Electronic Supplementary Material (ESI) for Catalysis Science & Technology.

Electronic supplementary information

$CoMn_xO_y$ nanosheets with molecular scaled homogeneity: An excellent catalyst for toluene combustion

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Experimental

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Catalyst Characterization

X-ray powder diffraction (XRD) analysis was conducted using an x`pert3 powder equipment (PANalytical B.V., Netherlands) with Cu Kα radiation. The loading amount of the catalysts was determined by inductively coupled plasma-atomic emission spectroscopy (ICP-AES, Optima 2000DV, USA). The N_2 sorption measurements were performed using physisorption (ASAP 2020, Micromeritics, USA) at -196 ^{o}C. The mesopore specific surface area and the pore size distribution were calculated using the Brunauer-Emmett-Teller (BET) and Barrett-Joyner-Halenda (BJH) methods, respectively. The micropore specific surface area and volume from the micropore were calculated by the t-plot method. The pore volume was calculated according to the adsorption amount of N_2 at P/P_0 (the relative pressure) = 0.995. TEM images were obtained on a JEOL-2010F electron microscope operated at 200 kV. XPS analysis was performed on an AXIS-ULTRA DLD-600W spectrometer (Shimadzu, Japan) using Al Kα radiation as the excitation source. The binding energies were calculated with respect to the C (C,H) component of the C 1s peak fixed at 284.8 eV. H_2 temperature programmed reduction (H_2-TPR) and O_2-TPD experiments were carried out on a chemical adsorption analyzer (Autochem II 2920, Micromeritics). Before TPR measurement, ca. 30 mg of catalyst (40-60 mesh) was loaded to a quartz fixed-bed U-shaped microreactor (i.d. = 4 mm) and pretreated in an O_2 flow of 50 mL/min at 360 ^{o}C for 1 h. After being cooled at the same atmosphere to room temperature (RT) and then purged with a N_2 flow of 50 mL/min for 15 min, the pretreated sample was finally exposed to a flow (50 mL/min) of 5% H_2/Ar mixture and heated from RT to 550 ^{o}C at a ramp of 10 ^{o}C/min. O_2-TPD analysis: 50 mg catalyst was heated to 110 ^{o}C and purged with He for 1 h to remove surface H_2O. After being cooled at the same atmosphere to room temperature (RT) and then purged with a O_2 flow of 50 mL/min for 1 h, followed just by the flow of He for 1 h to remove physical absorption oxygen. Then the catalyst was heated from 100 to 600 ^{o}C at a rate of 10 ^{o}C min.

Table S1. Preparation conditions, BET surface areas, pore volumes, average pore sizes, and H_2 consumption of the Co_3O_4 and MnO_2 catalysts.

Catalyst	Preparation method	S_{BET} ^{a} (m^2/g)	P_v ^{b} (cm^3/g)	APD ^{c} (nm)	H_2 consumption ^{d} (mmol/g)
Co_3O_4	prec.	20	0.035	36.1	15.7
MnO_2	prec.	14	0.031	40.6	6.8

^{a} BET specific surface areas determined from the linear part of the BET equation (P/P_0 = 0.05-0.25). ^{b} The total adsorption pore volume at P/P_0 = 0.995. ^{c} Average pore diameter (APD). ^{d} The data were estimated by quantitatively analyzing the H_2-TPR profiles.

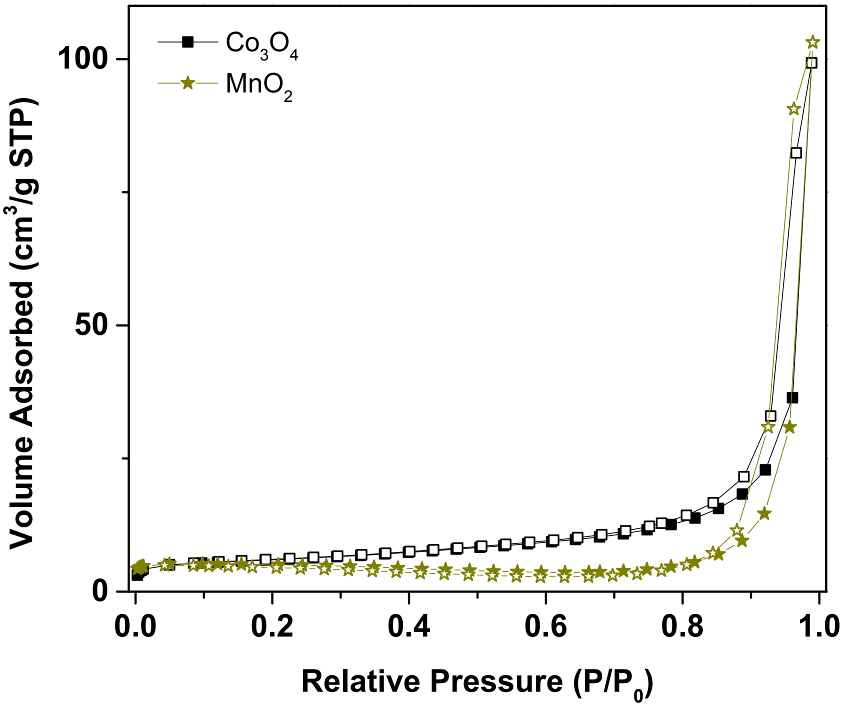

Fig. S1. N_2 adsorption-desorption isotherms curves of the as-synthesized Co_3O_4 and MnO_2 catalysts.

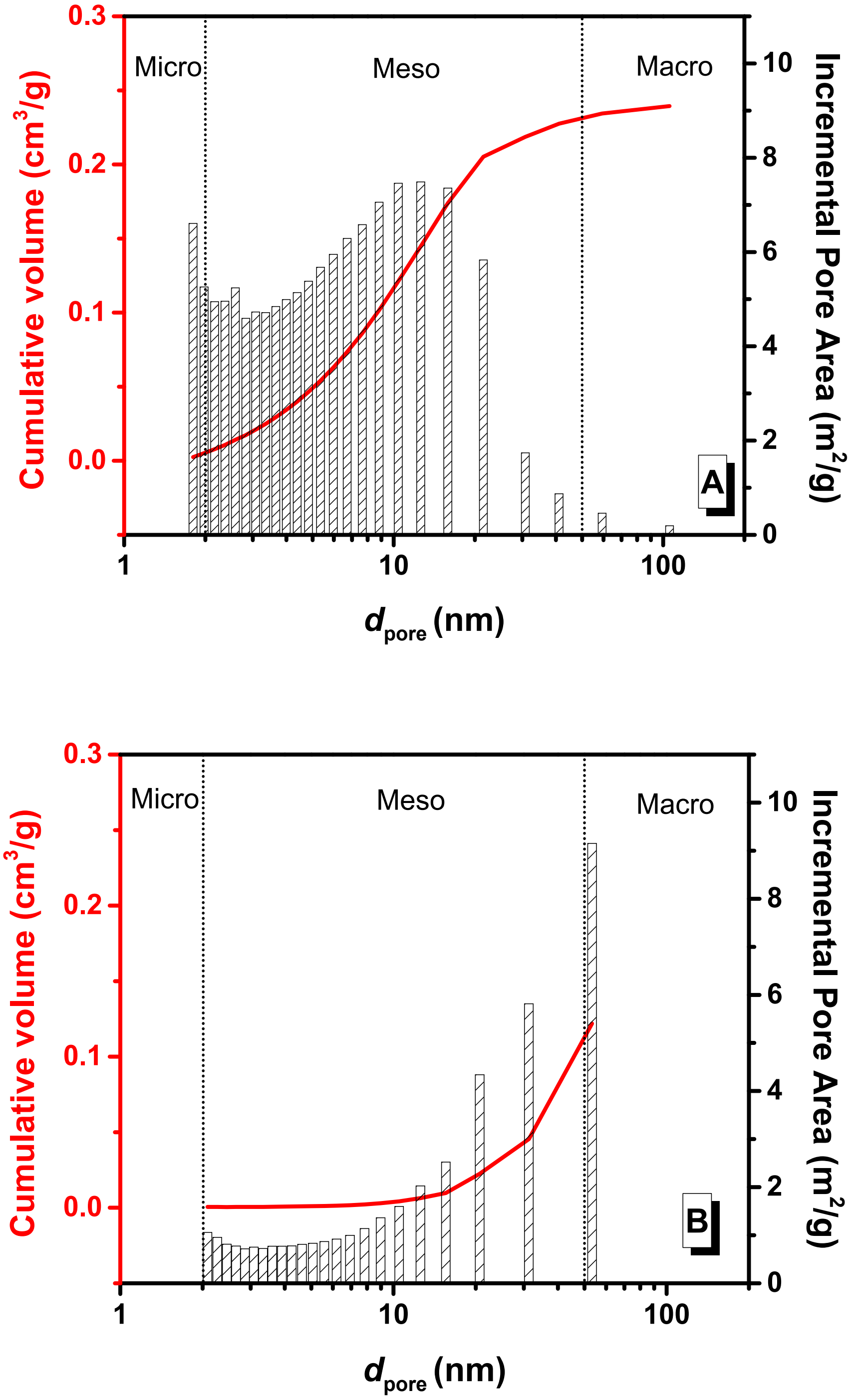

Fig. S2. Pore size distribution (PSD) of the (A) C3M1-R and (B) C3M1-C catalysts.

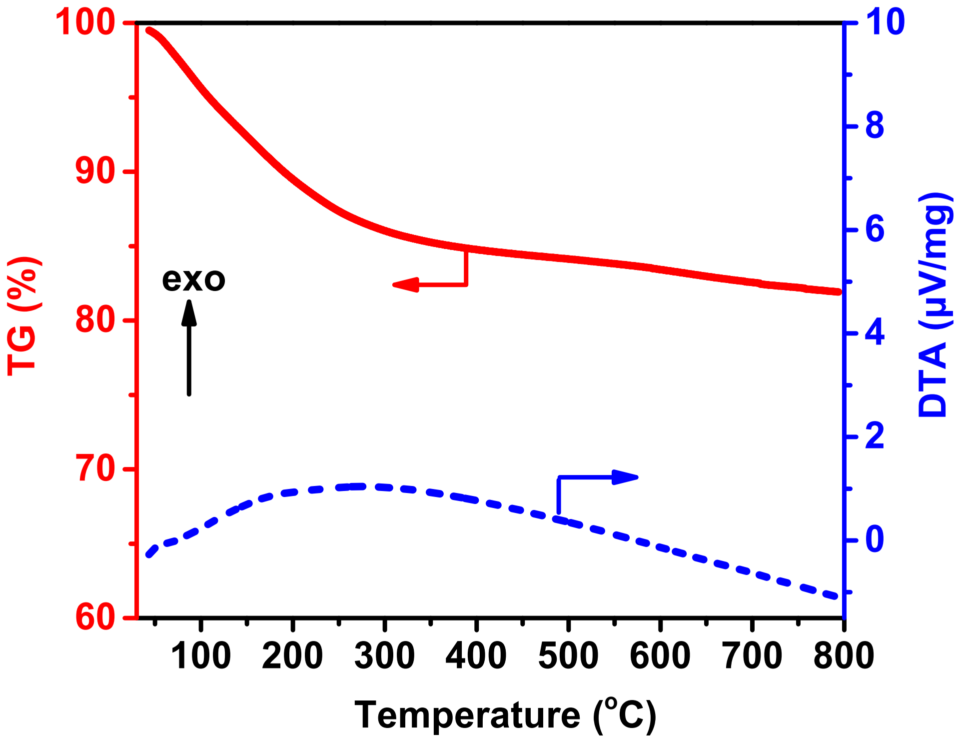

Fig. S3. TG-DTA data for the decomposition of the C3M1-R in air.

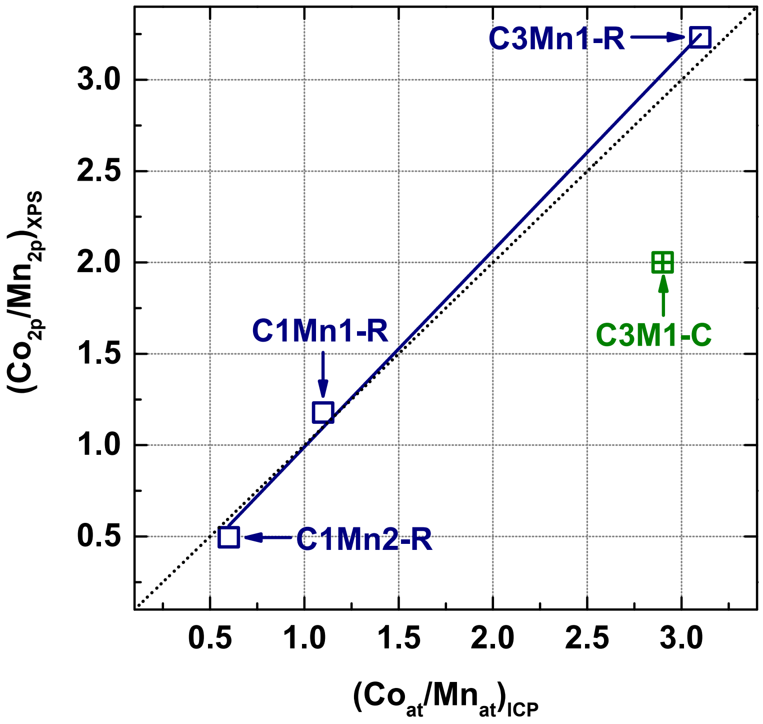

Fig. S4. Surface Co/Mn atomic ratio from Co 2p/Mn 2p signals (XPS) ratio vs the bulk (ICP) atomic composition of the $CoMn_xO_y$ catalysts.

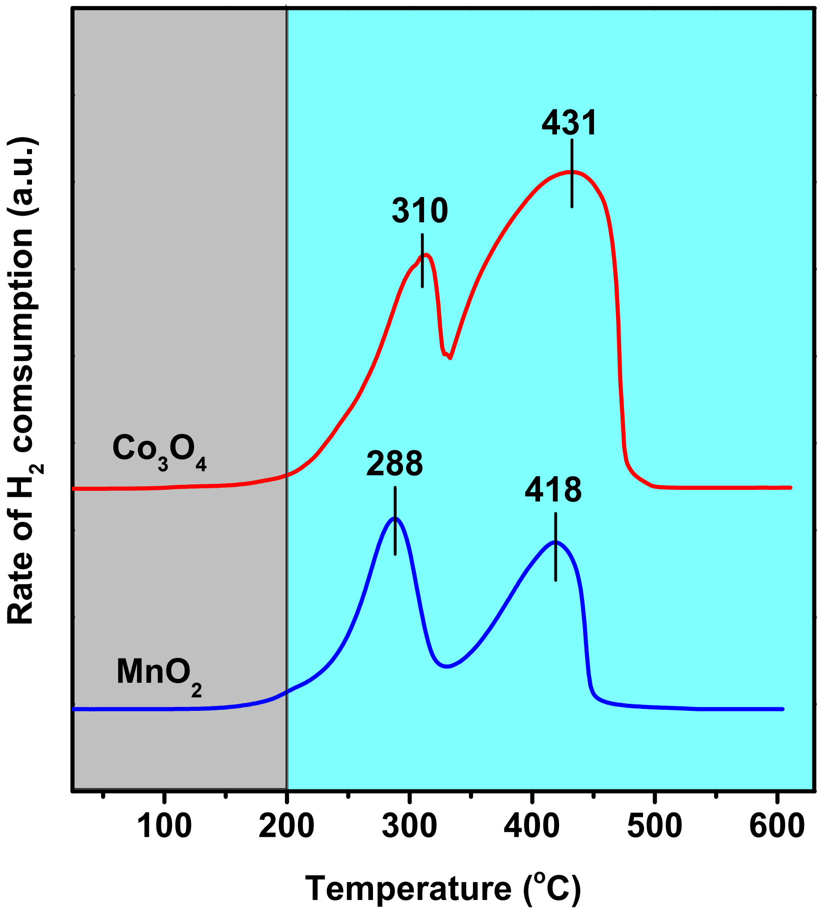

Fig. S5. H_2-TPR profiles of the Co_3O_4 and MnO_2 catalysts.

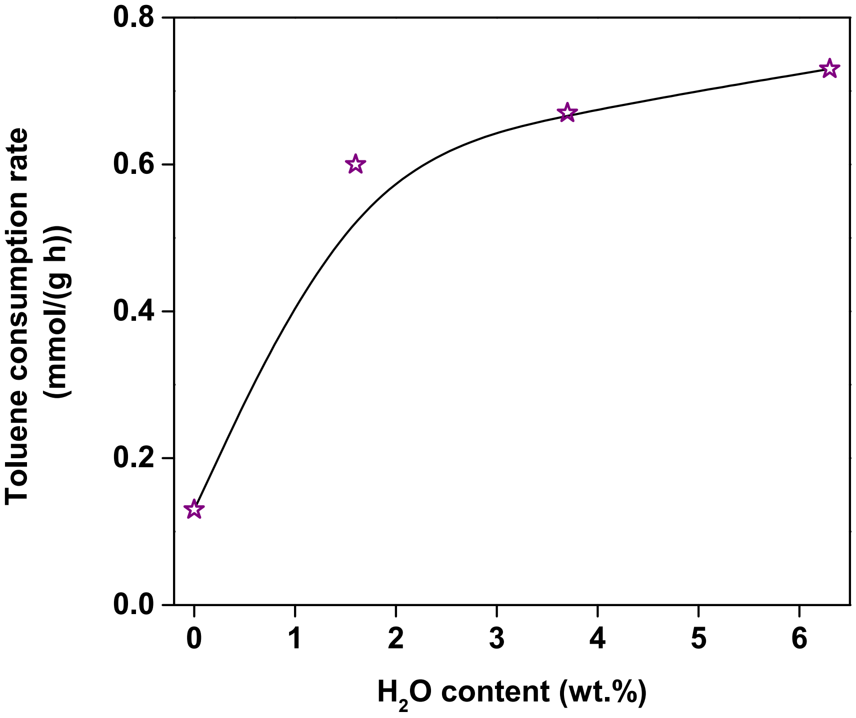

Fig. S6. Toluene consumption rates versus H_2O content of the C3M1-R catalyst.

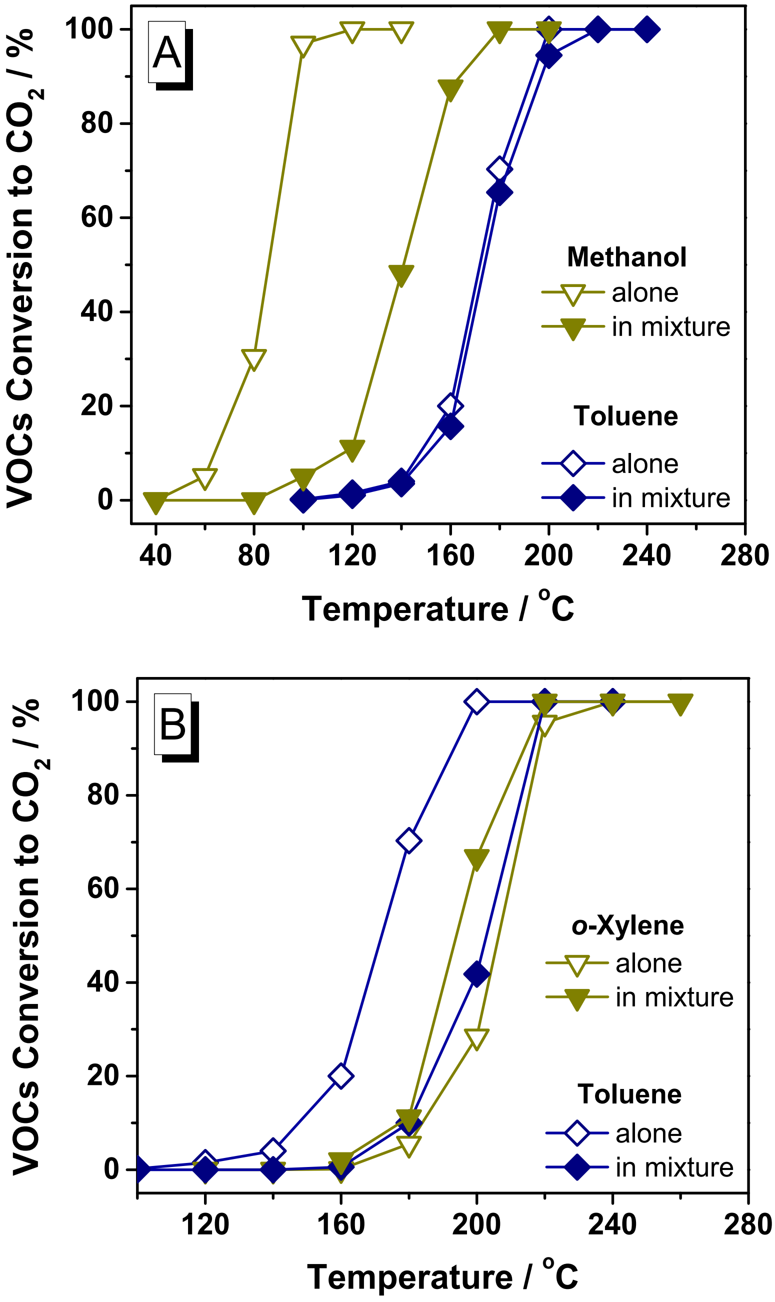

Fig. S7. (A) Comparison of toluene and methanol conversion alone or in mixture over the C3M1-R catalyst (Toluene alone: 500 ppm toluene/1.6 wt.% H_2O/10 vol.% O_2/N_2; methanol alone: 1000 ppm methanol/1.6 wt.% H_2O/10 vol.% O_2/N_2; mixture of the two VOCs: 500 ppm toluene + 1000 ppm methanol/1.6 wt.% H_2O/10 vol.% O_2/N_2, GHSV = 67,500 h^{-1}); (B) Comparison of toluene and *o*-xylene conversion alone or in mixture over the C3M1-R catalyst (Toluene alone: 500 ppm toluene/1.6 wt.% H_2O/10 vol.% O_2/N_2; *o*-xylene alone: 500 ppm *o*-xylene/1.6 wt.% H_2O/10 vol.% O_2/N_2; mixture of the two VOCs: 500 ppm toluene + 500 ppm *o*-xylene/1.6 wt.% H_2O/10 vol.% O_2/N_2, GHSV = 67,500 h^{-1}).